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A COMPARISON OF NUMERIC DATA ENTRY WITH
TOUCH-SENSITIVE AND CONVENTIONAL NUMERIC KEYPADS

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AFAMRL-TR-85-007

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The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-3.

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FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
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This report describes two experiments designed to establish data entry characteristics of touch-sensitive numeric keypads on a CRT versus conventional telephone keypads. In both experiments, data entry consisted of entering a series of four digit numbers (displayed in sequence on a CRT) on a specified numeric keypad. In experiment 1 two touch-sensitive keypads with telephone keypad dimensions were compared to conventional telephone keypads. One of the touch-sensitive configurations included audible feedback; one conventional keypad was mounted on a sloped box on the desk, the other was mounted on the CRT. In experiment 2 four different touch-sensitive keypad configurations were tested. Results indicate that the conventional keypads were superior in both speed and accuracy to all touch-sensitive configurations tested. Accuracy of data entry with touch-sensitive keypads was significantly improved with modified keypads used in experiment 2. In particular, it was concluded that sensitive areas should extend beyond visible keys, to include all of the area between keys. Additional keywords: man computer interface, speed, accuracy,

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INTRODUCTION

Performance and design data for conventional keyboards are well established. In contrast, similar data for data entry using touch-sensitive surfaces (e.g., CRT's, plasma panels) is almost nonexistent. The increased use of such displays creates an immediate need for such data.

Touch-sensitive display surfaces have several characteristics that make them attractive for human-computer interface applications. Among these are the ability to dispense with the conventional keyboard, thus making the area in front of a display available for other purposes, and the fact that data output (message to the operator) and input (operator response) can take place on a common surface. Probably the most attractive characteristic is the ability to completely control (with software) the format of input devices. For example, in the process of performing a given task using a touch-sensitive CRT, an operator may be shown a set of touch "switches" for performing a number of functions, may respond to queries by touching specified areas on the screen, and may be shown a numeric keypad for the entry of requested numeric data. The capability to dynamically identify (with color or brightness coding, for example) active function "keys" is a further example of the flexibility provided by a software controlled touch-sensitive display.

For the reasons mentioned, among others, touch-sensitive displays are finding increased application. Unfortunately, available data relating to the human factors characteristics of the devices is meager. Questions relating to optimal size and spacing of the "keys" on touch-sensitive panels, for example, cannot be answered with the data currently available. The relative performance, in terms of speed and accuracy of touch-sensitive displays and conventional keyboard/CRT combinations have not been established. The 1983 edition of the NRC report, <u>Research Needs for Human Factors</u> states, "No empirical data were found dealing with the touch panel." This conclusion is supported by the results of a search of recent human factors literature. No reports of empirical data obtained for touch-sensitive display data entry performance were discovered.

A number of issues specific to touch-sensitive data entry appear worthy of investigation. Fundamentally, effective design of touch-sensitive display formats requires guidelines for (1) the desirable size, shape, and spacing of touch-sensitive areas ("buttons", "keys", or "switches") on the display, (2) the relationship of illuminated and touch-sensitive areas (should the sensitive area of a "switch" be the same size, or larger than the illuminated "switch" area visible to the operator?), (3) desirable feedback for touch-sensitive input, (4) the best location for input areas on the display, and (5) the effect of viewing position on data entry accuracy. Additionally, the performance tradeoffs of touch-sensitive displays versus the conventional keyboard/CRT combination need to be established. The experiments discussed here addressed a number of these issues. Specifically, accuracy and speed of data entry via touch-sensitive numeric keypads were compared to that of a conventional numeric keypad. Performance effects of adding audible feedback to the touch-sensitive keypad were also assessed.

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METHOD

A pair of experiments were conducted to characterize numeric data entry via touch-sensitive keypads. Experiment 1 directly compared operator speed and accuracy with touch-sensitive versus conventional keypads. In Experiment 2, performance with four different touch-sensitive keypad configurations was compared.

Subjects

Subjects for both experiments were paid members of a subject pool. Both male and female subjects were used; all had normal or corrected-to-normal visual acuity, and had no neuromuscular disorders that would interfere with data entry. All were between 18 and 30 years of age. Six subjects participated in the first experiment. The same six, plus two additional subjects took part in the second experiment.

Apparatus

Data to be entered by the subjects, as well as feedback information and touch-sensitive keypads, were displayed on a 13", 512 line Hitachi color video monitor mounted approximately 20 inches in front of the subject. The display/input surface was perpendicular to the table top. The monitor was equipped with a TSD Display Products, Inc. Model TF-15 touch film overlay. The TF-15 uses a resistive film technology, and was adjusted to provide a 255 x 255 grid of touch-sensitive areas on the display. Conventional keypads used were standard touch-tone telephone keypads. Display software and data acquisition routines were run on a PDP 11/34 computer.

Design and Procedure

Experiment 1. The goal of Experiment 1 was to acquire fundamental data relating the performance of touch-sensitive and conventional keypads. Subjects sat in front of the touch-sensitive display surface, with right hand resting on a "home" switchplate. A four digit number appeared in the upper left corner of the display, accompanied by a short beep. The subject was instructed to respond by entering the displayed four-digit number as quickly and accurately as possible on the keypad under test. Motivation to work quickly and accurately was provided by feedback to the subject; both the actual digits entered and the time to enter all four digits were displayed on the video monitor. If a subject took more than 2.25 seconds to enter all four digits (after moving hand from the home switch) an audible alarm sounded. Following entry of each four digit number, and subsequent feedback, subjects replaced their hand on the home switchplate. After a variable delay of 1.5 to 3.0 seconds, the next number to be entered was displayed, and the sequence continued.

The four digit numbers to be entered by subjects were generated randomly but checked to ensure that no more than two consecutive digits in any number were the same (e.g., numbers such as 1333 and 4447 were not used). In the first experiment four keypad configurations were tested. Configura-

tion 1 consisted of a touch-sensitive video keypad displayed in the center of the video monitor. Dimensions were identical to those of the conventional telephone keypad used in Configurations 3 and 4 (See Figure 1). Configuration 2 was the same, except that audible feedback in the form of a short beep occurred when each number was entered. In Configuration 3 a conventional telephone keypad was positioned on the desk in front of the video monitor. The keypad was mounted on a small box with a sloping top to allow convenient data entry. Configuration 4 used an identical telephone keypad, but in this case the keypad was mounted on the face of the video monitor, in the location at which the video keypad was displayed in Configuration 1 and 2.

Each of the six subjects participated in four experimental sessions. In each session, the subject entered 100 four-digit numbers with one keypad configuration, took a short break, entered 100 numbers with the next configuration, and so on, for all four configurations. The order in which the four keypad configurations were presented conformed to a Latin square design.

Data acquired during each trial included the time delay between the hand leaving the rest position and entry of the first digit (termed "initial delay"), time between entry of digits ("inter-digit delay"), and data entry errors. The latter included the case of wrong digits entered, as well as the case (for the video keypads) of a touch occurring outside of any touch-sensitive area. The coordinates of each touch on the video keypads were also recorded.

Experiment 2. The second experiment built, on results of the first, was very similar in design. Eight subjects were used, including the six who participated in Experiment 1. Four potential video keypad designs were studied. Configuration 1 was identical to that of the first experiment—a video keypad matching telephone keypad dimensions. The other three configurations are numbered 5 through 7 to avoid confusion with the first experiment. In Configuration 5 (Figure 2) the video keypad was visually identical to Configuration 1, but the areas sensitive to touch were extended beyond the visible key areas. Both key spacing and key size were expanded in Configuration 6 (Figure 3); visible and touch sensitive key areas were congruent. In Configuration 7, shown in Figure 4, key sizes were identical to standard keys, key spacing was increased, and touch-sensitive areas extended beyond the visible keys. No audio feedback was provided for any configuration.
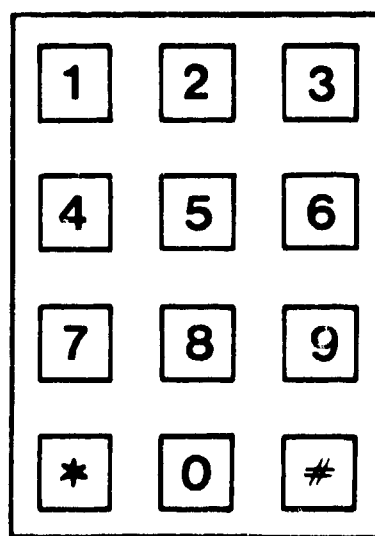
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FIGURE 1.   Telephone Keypad: Dimensions used for
            Configurations 1, 2, 3, and 4.

(Sensitive areas are congruent with the visible keys)
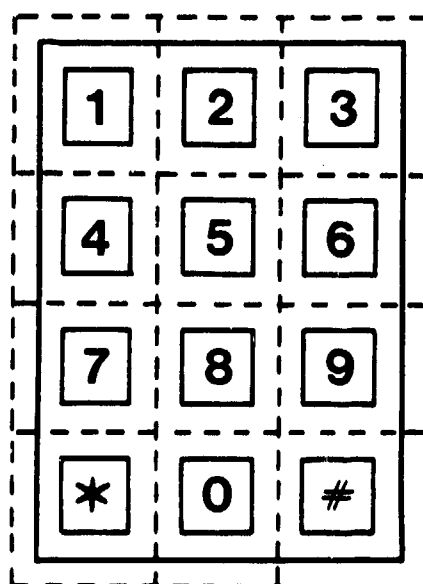
FIGURE 2. Configuration 5: Telephone Keypad with
            Increased Sensitive Area

(Sensitive areas are contained within the dotted lines)
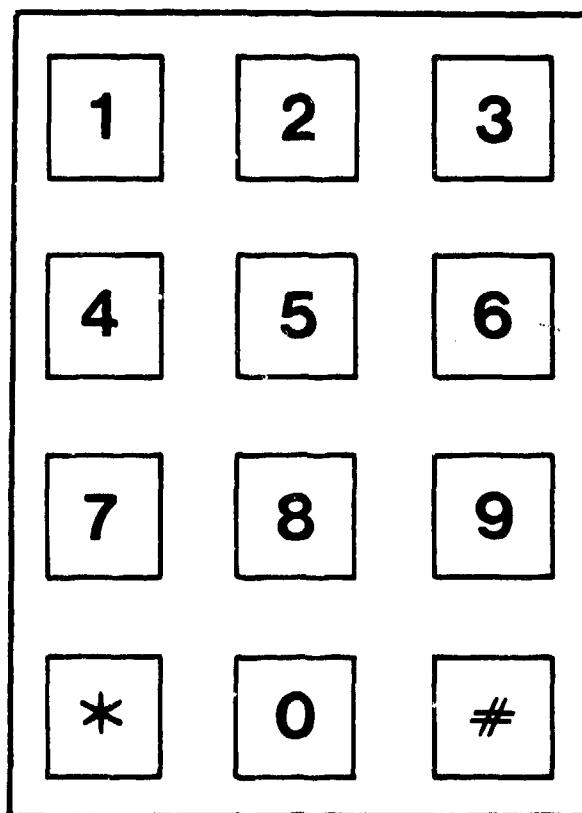
FIGURE 3. Configuration 6: Enlarged Telephone
Keypad

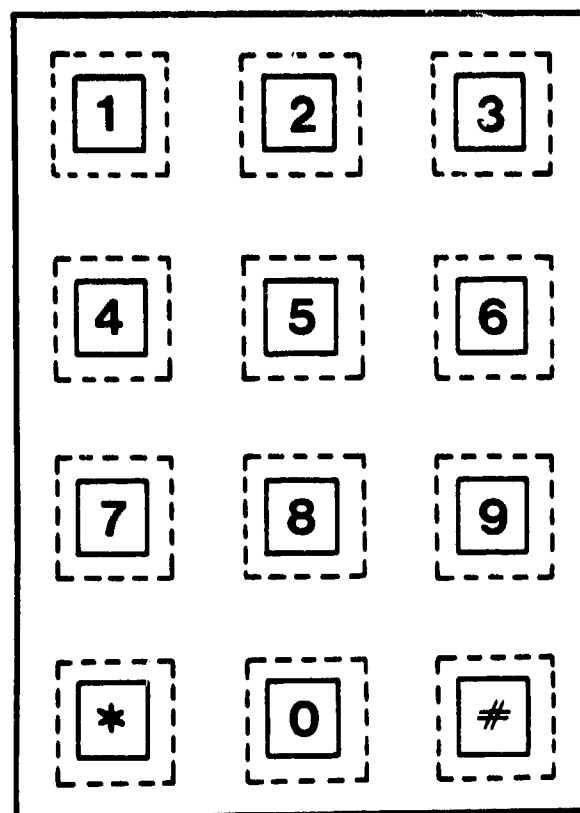(Sensitive areas are congruent with the visible keys)

FIGURE 4.   Configuration 7:   Telephone Keypad with
             increased spacing

(Sensitive areas are contained within the dotted lines)

RESULTS

In this section, results for Experiments 1 and 2 will be discussed together. Delay and error data will be treated in turn. Table 1 shows mean delays and error rates for both experiments; Table 2 shows corresponding Analysis of Variance (ANOVA) results.

Delays

Delay data for both experiments is graphed in Figure 5. A learning effect is clearly apparent in data for the first experiment.

The ANOVA results indicate that the observed differences are significant. Particularly apparent is the larger initial delay observed for all touch keypads (Configurations 1, 2, 5, 6, 7) compared to the conventional keypads (Configurations 3, 4). For example, mean initial delay during the fourth session for all touch keypads was approximately 670 milliseconds, compared to 565 milliseconds for the two conventional keypad configurations. A proportionate difference is evident for the interdigit delays.

Errors

Figure 6 shows that in the first experiment conventional keypads produced much lower error rates than the touch keypads. In the second experiment, however, new touch keypad designs showed improvement over the original configuration. Specifically, Configuration 5 demonstrated an error rate of 7.4 percent, compared to 18.6 percent for Configuration 1 (over all sessions). By comparison, the conventional keypads produced a combined mean error rate of 4.9 percent.

Questionnaires

Following the completion of each experiment, participants filled out a questionnaire. Results for Experiment 1 and 2 will be discussed in turn.

Questionnaires for Experiment 1 were completed by eight subjects, including two who participated only in pilot testing. When asked which Experiment 1 condition they would most prefer to repeat, subjects listed only Configurations 3 and 4, those using the conventional telephone keypads. When asked which they would least prefer to repeat, each video keypad configuration received two responses, and Configuration 3, the conventional keypad mounted on a sloping box on the desk, was listed three times. Asked to list any conditions that caused discomfort, subjects listed the video keypad conditions ten times; Configurations 3 and 4 were listed two and four times respectively. Finally, six subjects felt that audio feedback for the video keypad was helpful, two thought it was not.

In Experiment 2, Configuration 7 (increased key spacing, small keys with expanded sensitive area) was judged most preferred by five subjects. By a wide margin (six responses), Configuration 6 (large visible keys and increased spacing) was judged least preferred.. Finally, five subjects

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thought they were most accurate with Configuration 7, two thought they were most accurate with Configuration 5 (telephone layout, increased sensitive areas).

TABLE 1. ANOVA Results for Experiments 1 and 2

VARIABLES		df	INITIAL DELAY		INTERDIGIT DELAY		% ERRORS	
			F	p	F	p	F	p
Conditions,	Exp 1	3,15	7.61	.003	9.60	.001	32.37	.000
	Exp 2	3,21	4.79	.011	6.95	.002	26.69	.000
Sessions,	Exp 1	3,15	13.29	.000	10.09	.001	<1	ns
	Exp 2	3,21	2.28	.109	6.40	.003	1.03	ns

TABLE 2. Mean Initial and Interdigit Delays and Error Rates for
Experiments 1 and 2

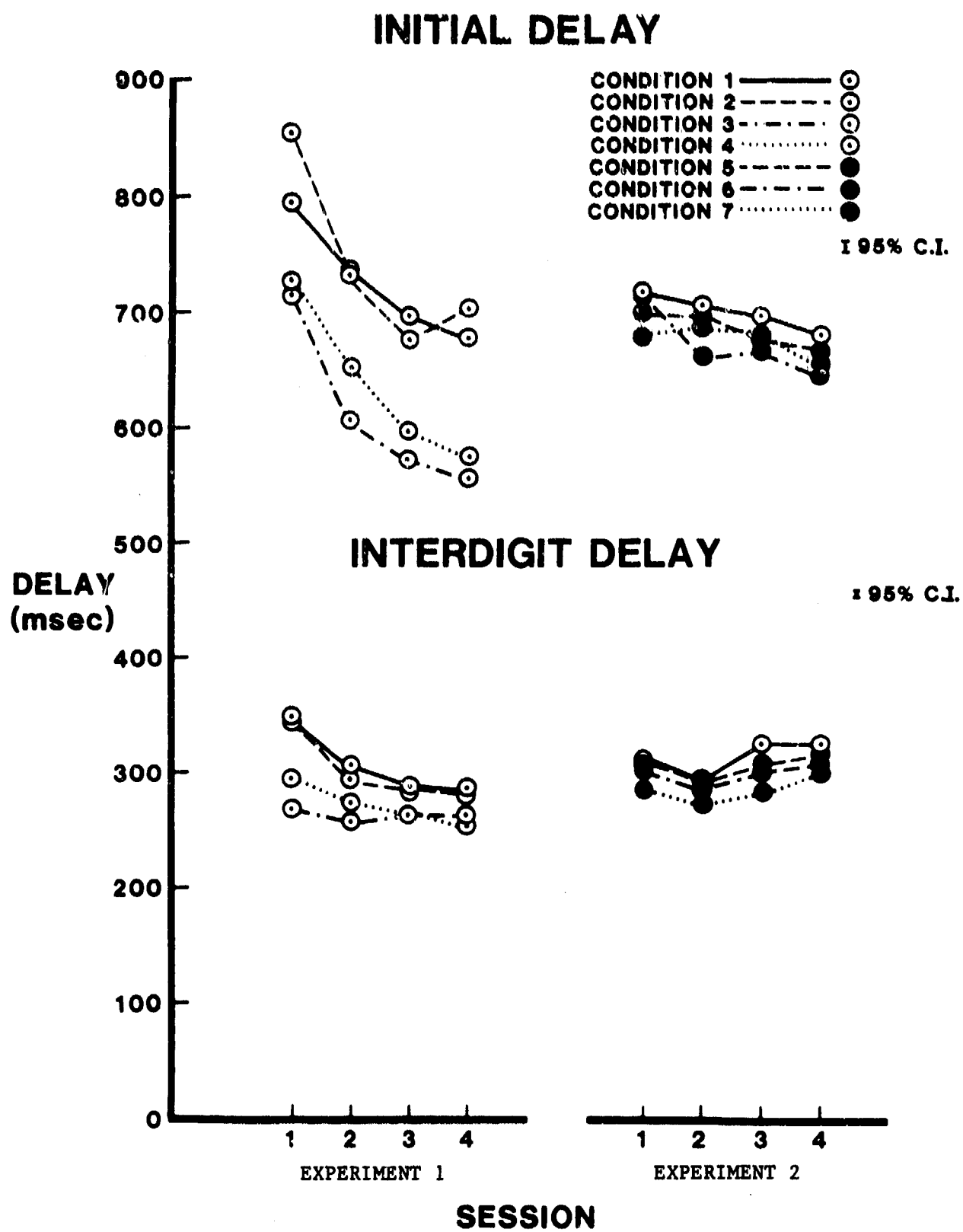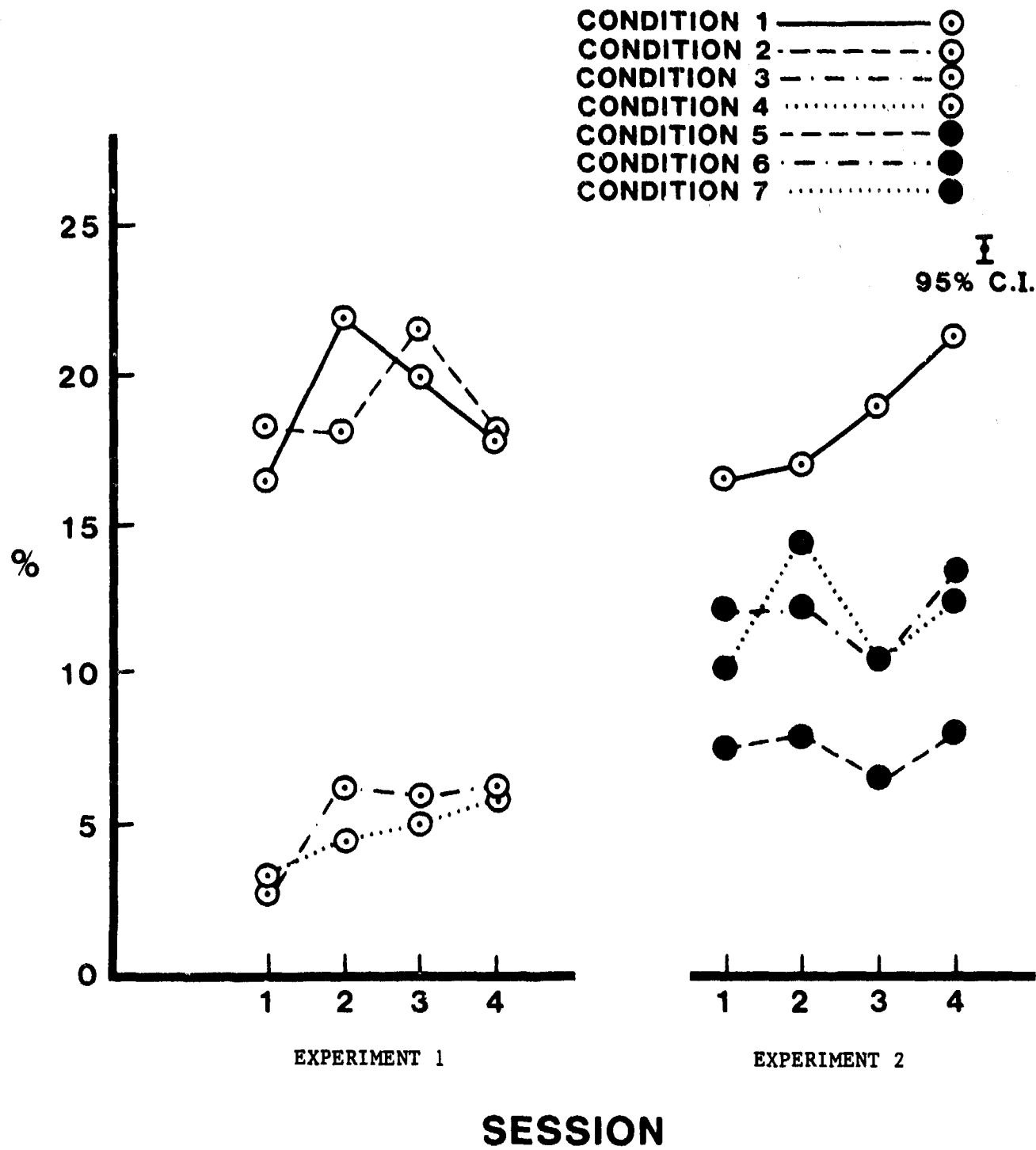|		INITIAL DELAY		INTERDIGIT DELAY		% ERRORS	
		Mean	s.d.	Mean	s.d.	Mean	s.d.
Exp 1	Condition 1	726	102	295	49	18.9	10.6
	Condition 2	741	114	295	45	18.9	11.1
	Condition 3	610	129	262	40	5.2	6.2
	Condition 4	637	114	269	48	4.6	3.6
Exp 2	Condition 1	699	89	301	46	18.4	10.0
	Condition 5	683	103	284	49	7.4	4.8
	Condition 6	671	95	303	52	12.1	7.7
	Condition 7	673	92	310	52	10.9	6.2

FIGURE 5. Data Entry Delays

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FIGURE 6. Data Entry Errors

SECTION 4

DISCUSSION

Experiment 1 showed conventional keypads to be superior to the touch keypad configurations in both speed and accuracy. Curiously, initial delays (time from home position on the desk to entry of the first digit) for the conventional keypad mounted on the CRT were considerably less than for the touch keypads displayed in the same location. Two factors possibly contribute to the observed difference. First, anticipated tactile feedback may increase confidence that the correct number will be entered on the conventional keypad, with a resulting increase in speed. Second, the three dimensional characteristics of the physical keypad may assist accurate and speedy aiming.

New touch keypad configurations studied in the second experiment showed little speed advantage over the original configuration. On the other hand, the designs all resulted in reduced error rates. In particular, Configuration 5, in which the keypad remained visibly identical to a telephone keypad yet had extended sensitive areas, gave error rates approaching those of the conventional keypads. Conditions in which key spacing (Configuration 7) or both key spacing and visible key size were increased (Configuration 6) resulted in error rates higher than for Configuration 5, with little or no speed advantage. The greatest improvement, then, was achieved by allowing sensitive areas to fill the space between the keys, eliminating the possibility of an error resulting from completely missing a target key. The resulting increase in wrong digits entered was more than compensated for by the decrease in errors due to the target being completely missed.

At first glance the similar performance with both conventional keypad positions (on the desk and on the display) was surprising. It seems to indicate that keypad position does not have an important effect on speed of data entry. This counter-intuitive result may be a product of confounding due to the position of the input cue. Several subjects noted that they preferred the keypad on the CRT because it was in the same visual field as the four digit number they were required to enter. This advantage over the keypad on the desk probably compensated for any disadvantage due to distance from the home hand position.

The presence or absence of audible feedback with the video keypads in the first experiment had little effect on speed or accuracy. Although several subjects indicated that they liked the feedback, others felt it was merely annoying.

Questionnaire responses after the first experiment heavily favored the conventional keypad conditions. The two conventional keypad configurations were the only ones noted as "most preferred to repeat." The conventional keypad mounted on the CRT was the only configuration not mentioned as "least preferred to repeat," and the keypad on the sloping box was noted least often as causing discomfort. In general, subject responses following Experiment 1 were consistent with the performance achieved; those configurations with lowest performance were liked the least. This was not the case following the second experiment. Although Configuration 5 resulted in

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the best overall performance, five subjects preferred Configuration 7 (greater spacing, small keys, large sensitive areas), and five felt they were most accurate with that condition. Curiously, six subjects responded that they would least like to repeat the condition with increased spacing and large visible keys (Configuration 6).

SECTION 5

CONCLUSIONS

Error rates and delays achieved with the conventional keypads were superior to all touch-sensitive keypad configurations.

Although subjects expressed some preference for audible feedback with touch-sensitive keypads, speed and accuracy were not affected.

Although initial and interdigit delays were similar for all touch-sensitive keypad conditions, a large and significant improvement in error rate was achieved by modifying the initial design.

Increasing video keypad visible key size and key spacing resulted in improved accuracy compared to the video keypad with standard telephone dimensions (Configurations 1 and 2). Similarly, increased key spacing, with small keys and extended sensitive areas gave improved accuracy. The improvement in each case was less than for the condition in which standard telephone dimensions were used with increased sensitive areas.

The most effective modification was simply to extend the sensitive area for each key until it bordered the sensitive areas for neighboring keys, and extended outside the visible boundaries of the keypad. The fundamental conclusion is that sensitive areas should be extended to fill all of the area between numeric keypad keys. More generally, sensitive areas should be extended whenever possible beyond the visible target area on any touch-sensitive display format.

Data for all video keypads is consistent with the conclusion that the most effective design step for best data entry accuracy is to expand touch-sensitive areas to fill the entire area between visible keys.